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MICHIGAN POTATO DISEASES

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MICHIGAN AGRICULTURAL COLLEGE

BOTANICAL SECTION

East Lansing, Michigan

This bulletin contains a description of the serious diseases which cause a shortage in the potato crop of Michigan. There is also given a definite program for handling the crop so that this great leak in our agriculture can be stopped.

Michigan Potato Diseases

BY G. H. COONS AND J. E. KOTILA

The bulletin is a brief handbook of potato diseases. The diseases are arranged according to methods of control employed and the salient facts about each disease are given in connection with an illustration which shows the characteristic signs by which the disease may be recognized. The causal agent, when known, is discussed and its life history told. Methods of control based upon life history of the parasite are then given. These control measures are general and outline the principle involved in the treatment. A definite program recommended for potato growers is given on the last pages of the bulletin. Here also the making of bordeaux mixture is outlined.

THE CAUSES OF PLANT DISEASES

By "plant disease" we mean for plants the same sort of thing as is meant by the term "animal disease." A plant which departs from the normal in directions dangerous to the life of the plant is in the broadest sense of the term, "diseased." Farmers know very well the types of disorder which come from weather or soil conditions. They understand the effects of insect pests. They are less familiar with the disorders which arise from the attacks of plant parasites. The plant parasites which attack our crops are either *fungi* or *bacteria*. A parasitic fungus is a microscopic plant which makes no food for itself, but which steals its living from another plant. The body of the fungus consists of threads which grow in or upon the sick plant which is thus used as the source of food. Fungi are spread by spores—small bodies which are the "seeds" of the parasite. They are produced in countless numbers and are small and light enough to be blown about by small currents of air or by the wind, or else they may be splashed about by rain.

Other diseases are caused by bacteria—minute rod-shaped plants which consist of a single cell. These cells are commonly motile and swim about in water by means of minute whip-like outgrowths. Bacteria are remarkable in the rapidity of their growth and multiplication. Under favorable conditions, they merely elongate and cut in two, and hence from one organism in the course of an hour or less, two arise. Each of these in turn produces two more, and so in the course of a day countless numbers arise from the one germ.

THE PRINCIPLES OF DISEASE CONTROL

The farmer can fight plant diseases intelligently only by knowledge of the life story of the parasite, its mode of life, its method of injury, and its ways of spreading. The methods of plant disease control in general fall into three groups:

1. Sanitary and hygienic measures.
2. Plant protection measures.
3. The use of resistant varieties or strains.

The first of these means clean seed in clean soil, or better, *safe* seed in *safe* soil, since no stock of seed potatoes exists entirely free from all potato diseases, and practically all soils contain some organisms capable of attacking the potato. Accordingly, as a sanitary measure, attempt should be made to use as clean tubers as possible for seed purposes, and soils should by their handling be kept as free from serious parasites as possible. Sanitation is probably the most important of all disease control measures and the one most easily practiced.

The second has to do with actual treatment of plants, spraying with fungicides, in order to protect them from fungous invaders.

In the third method of plant disease control lies the hope of the future. Under this head are included disease-tolerant and disease-escaping forms, and varieties and strains which, due to some inherent protoplasmic quality, resist parasitic attack. The discovery or the development of such strains alone will emancipate us from the enormous toll which parasites levy. While some disease-resistant strains exist, long research and trial yet remain before the ideal disease-resistant potato plant is produced. Scientific investigation alone can solve this problem for agriculture.

Diseases Controlled by Spraying with Bordeaux Mixture

LATE BLIGHT OF THE TOPS; ROT OF THE TUBERS

Economic Importance:

This is probably the most destructive of all potato diseases. Periodically great epidemics of this disease sweep the great potato-producing states, destroying from a quarter to one-half of the total potato crop of the nation. The disease cost Michigan, according to conservative estimate, $2,000,000 in 1912 and $4,000,000 in 1915. Since 1915 there has been no wide-spread outbreak of late blight, but various small districts have had epidemics which have caused a high percentage of loss.

Signs—On leafy parts:

Blighting begins at tips or edges of leaflets and makes dark, greasy appearing or watersoaked spots, usually involving one-third to one-half of the leaflet when first noticed. The under surface of a leaflet so affected

appears filmy or cowwebby with the fruiting threads of the fungus. (Fig. 1.) Under wet conditions, all tender parts of the tops blight and quickly rot away, with a characteristic, rank odor. A blighted field looks as if struck by frost.

Fig. 1. Underside of leaf showing spots characteristic of late blight. Note white mold growth at edges of spots.

On the tubers:

In the first stages of rotting, the affected tubers show slightly sunken, lead-colored or pinkish areas. (Fig. 2.) Sometimes these are mere depressions here or there, making the tuber look hob-nailed. Under moist conditions in storage or when dug from wet fields, the potatoes may show grayish-white tufts of the fungus. These are fruiting threads such as have been mentioned before as occurring upon the leaves. Rotting is most serious with tubers grown on heavy soil.

The flesh beneath the sunken skin is brown. (Fig. 3.) When the skin is scratched away the tell-tale brown discoloration of the flesh indicates the blighted condition of the tuber which makes it unsafe to ship or store. As the blight advances in the tuber, more and more of the flesh is involved and the color of the rotted flesh changes to black. If the storage conditions are dry, the tuber wizens into a mummy—"dry rot." If the tubers are kept wet, or even moist, as in the car, they rot with an ill-smelling, slimy rot, "wet rot."

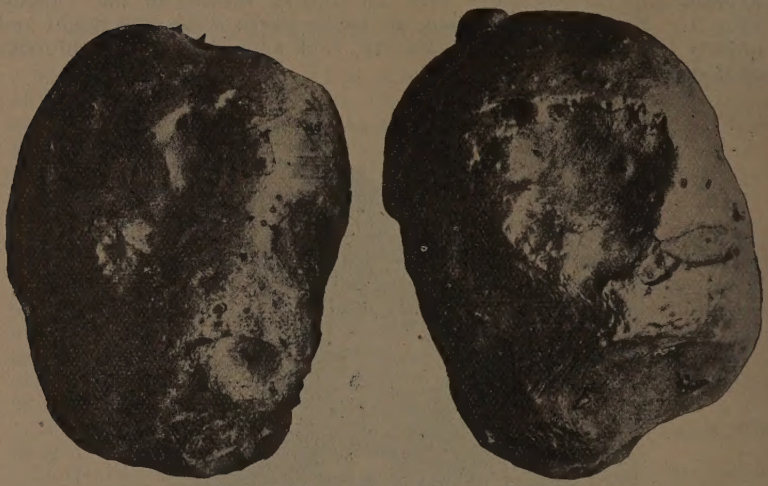


Fig. 2. Tubers affected with late blight.

The cause:

A parasitic fungus, *Phytophthora infestans* (Mont.) de Bary, which is restricted in its attack to the plants of the potato family, causes this disease.

The life history of the causal organism:

The fungus is probably carried to the field as a lurking infection in practically every lot of tubers planted. No experiments have been able to demonstrate that the fungus lives over winter from crop to crop in the soil. The majority of sprouts which arise from infected seed tubers are weak and subject to rotting in the ground, thus giving

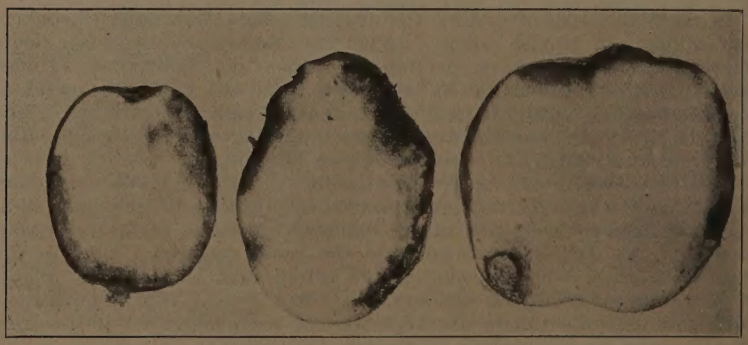


Fig. 3. The effect of late blight in the flesh of the potato tuber.

a poor stand. However, under favorable weather conditions a few infected sprouts get above the ground and communicate the disease to nearby plants. Given favorable weather conditions to promote spread and growth of the spores of the fungus in the first half of the growing season, the disease spreads from plant to plant and becomes established throughout the field. With such an entrenchment of the fungus in the field, even moderately wet weather the last half of the season is sufficient to bring about a blight epidemic. To the farmer, the blight seems very sudden in its action, but in reality the fungus has been establishing itself for more than a month.

Rotting of the tubers comes about from spores washed from the tops through the soil, or shaken upon the tubers at digging time. It does not come about from the fungus working down the stalk as is generally supposed. An examination of the blighted areas on the tuber will show this beyond question. Occasionally the fungous spores wash down along the stem and cause a rotting, in close-setting varieties, which begins at the stem end of the tuber.

A spore of this parasitic fungus, carried to the tuber, sprouts, if given favorable conditions of moisture and temperature, and bores through the skin. Once the fungus gets into the flesh of the tuber the advance is rapid. The browning of the flesh is an indication of the activity of the parasite. The rapidity of the progress of the rot depends upon the temperature of the storage cellar. Temperatures near the freezing point check the growth of the fungus. The advance of the fungus is very rapid if the storage cellar is warm. Moist conditions favor spore production and the spread of the rot in storage.

Weather relations:

A cool, wet July followed by an August with moderate or heavy rainfall always has given epidemics of late blight in the Lower Peninsula of Michigan. The Upper Peninsula, commonly having cool, wet seasons, has blight more frequently. The reason for this weather relation has already been explained. Some of the observations on which this statement of weather relations is based are given in the diagrams. (Figs. 4 and 5.) From these observations it is seen that we may predict with considerable accuracy at the close of July, if late blight is going to damage the crop. While we advise spraying every year as a good business policy, this method of prediction enables the College to warn the farmers as to when an epidemic is threatening. It behooves a farmer to be prepared with spray machine and copper sulphate if he is to take advantage of the danger signal and save his crop.

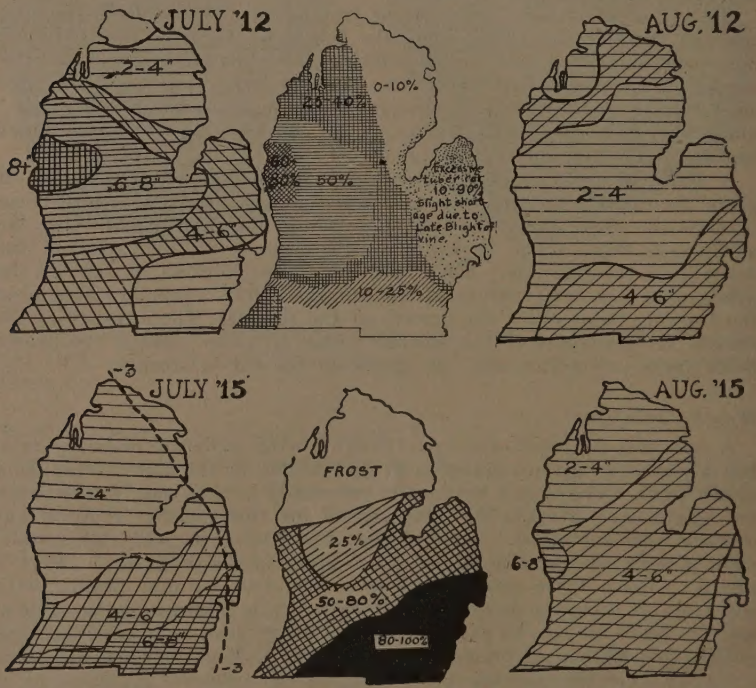
Control measures:

Probably no commercial seed stock available to the farmer is truly "blight-free," although some are advertised as such. Moreover, no practical method has been devised of ridding seed of blight infestation.

Tubers showing even slight evidence of rot should be sorted out, not that this sorting will eliminate blight, but because sprouts from such potatoes are notorious in giving a poor stand of weak hills. Sound tubers from a stock which has rotted from late blight are safe to plant, but the rotted tubers are dangerous.

The main control measure against late blight consists of the thorough application of properly made bordeaux mixture. Spray the plants every ten days or two weeks, beginning when the tops are 3 to 6 inches high. If you can raise 150 bushels or better, spray every year. Everyone should spray when the first half of the growing season (July) is cold and wet.

If protective sprays have been neglected, a crop can still be saved if the blight is recognized when first starting. When the tops are blackened and the foliage wilted, nothing can be accomplished by spraying.



Figs. 4 and 5. The rainfall (in inches) of July and August for 1912 and 1915 respectively, compared with the prevalence of late blight (Center Map). Note that the rainfall of July was decisive in determining areas of greatest loss.

Spraying seeks to prevent wholesale leaf infection. It prevents rotting of the tubers since it does away with the source of tuber infection, namely the diseased leaves.

When late blight is present on the tops of potatoes it is unsafe to dig the tubers so long as the tops are green. Where soil and weather conditions permit, the best practice is to allow the tops to die down and dry before digging. Digging immature potatoes while the tops are green and show blight infestation leads to heavy storage rotting. Pits should not be covered with potato tops.

In preparing for shipment or storage, sort out all tubers showing any signs whatsoever of blight. Such tubers are a sure source of loss. They are diseased in the field and they never improve. Some buyers will not handle potatoes from districts where blighting has occurred. Close sorting, frequently repeated, with cool, dry, well-ventilated storage minimizes loss. The great economic waste which arises from late blight is unnecessary and would be avoided if farmers adopted a rational spraying practice.

EARLY BLIGHT

Economic importance:

This disease causes loss because it prevents a crop of potatoes from becoming the maximum the soil is capable of returning. In years when early blight is prevalent the disease may reduce yields as much as 25 per cent. Late blight destroys a crop of tubers already produced, while early blight cuts down the possible size of the crop. This disease and hopperburn are largely responsible for the mediocre yields which come from seemingly well cared for fields.

Fig. 6. Early blight on leaves.

Signs—On the leaflets:

Small (one-eighth to one-fourth inch in diameter), black spots are produced on the leaflets. (Fig. 6.) These spots are more or less circular, except where two or more spots run together. Each spot represents a point of attack of the parasite and marks the place where a

spore germinated and entered the leaf. As the fungus grows in the tissue, the cells of the leaf die and turn black. The drying effect of the fungus upon the leaf tissue is represented by lines forming concentric rings about the spot. The "target-board markings" are a means of determining the disease.

On the tubers:

No direct rotting or marking is produced upon the tubers by this disease.

The tubers produced on diseased plants are smaller since the yield is reduced on account of the weakened leaves.

The cause of the disease:

A parasite fungus, *Alternaria solani* (E. and M.) J. and G., known to attack potatoes and tomatoes and possibly other solanaceous plants is the cause of this disease.

The life history of the causal organism:

The fungus which causes this disease probably lives over winter on trash, etc., in the soil. It is probably widespread in every field where potatoes are grown and must be recognized as a pest sure to be met with if the season permits. Spores from the trash finding a place on the leaves of the potato, germinate under wet conditions and cause the characteristic spots of the disease. On the diseased spot the fungus fruits profusely, producing the characteristic club-shaped spores of the fungus. These spores in turn are carried to fresh leaflets chiefly by wind and rain and thus from a few spots, countless points of infection result. This story is repeated over and over in the field so long as the weather relations favor infection. A spotted leaflet is weakened and sometimes turns yellow and dies.

The leaves of the potato are the manufacturing organs which make the starch which is stored in the tubers. Anything which interferes with the efficiency of these food-producing organs cuts down the yield of tubers.

The relation to the weather:

The disease, while present in more or less abundance each year in Michigan, is most severe in years when the season is warm and with moderate rainfall. The most severe effects of this fungus in the last few years have come from late attacks in September, and such attacks have been most severe in fields growing on moist locations and in fields with heavy vine growth.

Control:

The system of summer spraying outlined under the late blight of potatoes controls this disease and a consistent spraying program is recommended. To prevent the heavy losses which have come from late attacks of this fungus, the spraying program outlined should be kept up throughout the season.

HOPPERBURN (TIPBURN) OF THE LEAVES

Economic importance:

This trouble, like early blight, causes loss because it prevents a crop of potatoes from becoming the maximum the soil is capable of producing. It is the cause of the wholesale blighting and drying up of the leaves of potatoes during hot, dry seasons. Hopperburn was especially severe during the 1919 season and losses up to 25 per cent of the crop were reported from various states. The total loss to the United States potato crop in the season was reported as 3.7 per cent or 16,348,000 bushels. It was estimated that in Michigan alone the potato crop was reduced nearly 10,000,000 bushels that year. Hopperburn is without doubt one of the greatest factors reducing Michigan potato yields during the dry seasons.

Signs:

The leaflets die at the tips and edges. (Fig. 7.) The dead areas become brown and the leaves present a burned appearance which suggested the name "tipburn" by which the trouble was formerly known. Injured leaflets are curled upward slightly.

The injury starts at the tips and progresses more or less uniformly down the margins and then inward to the midrib until the entire leaflet is killed. The only effect on the tubers is the secondary effect which comes from early death of the tops.

Fig. 7. Hopperburn.

The Cause:

The potato leafhopper, *Empoasca mali* LeB., is the cause of hopperburn. This insect is a tiny green bug one-eighth of an inch long. For further information on hopperburn write to the Department of Entomology, M. A. C., East Lansing, Michigan.

Weather relations:

Whereas late blight usually causes serious losses in seasons in which the month of July is characterized by cold, wet weather, hopperburn occurs in epidemic form when the weather of June is hot and dry.

Resistance of varieties:

Early varieties, as a rule, are more susceptible than late varieties. In a variety test the Bliss Triumph was found to be most susceptible of the early varieties, followed in order by Early Ohio and Irish Cobbler. The Idaho Rural was found to be most susceptible of the late varieties and was followed in order by the Green Mountain, Russet Burbank and Rural New Yorker. The last variety is not immune and some burning has been observed on it, but the Rural varieties, both white and russet have some inherent quality whereby they are able to withstand insect and disease attacks better than the other varieties.

Effect of time of planting:

Hopperburn is especially severe on early planted potatoes In many sections those planted fairly late are not seriously affected because they come up after the spring flight of leafhoppers has taken place and remain comparatively free from the insects until the flight of the first generation adults which occurs during the latter part of July. Where danger from early fall frosts does not preclude the late planting of potatoes, the practice is suggested as a feasible method of combatting the leafhopper.

Preventive measures:

Potato leafhoppers are repelled and hopperburn prevented by spraying the vines with 4-4-50 bordeaux mixture.

For efficient control of hopperburn it is necessary that the spraying program be started before the over-wintering adults have migrated to the potato fields.

The first application of bordeaux should be made when the vines are from 3 to 6 inches high and should be followed by a second spraying about a week later. At least three subsequent applications should be made at intervals of 10 days or two weeks.

Best results are obtained by using a sprayer which is capable of maintaining a pressure of 200 pounds or more and which is equipped with a boom so arranged that two nozzles direct the spray upward and inward from each side of the row, while a third nozzle directs the spray downward and covers the upper surface of the leaves. It is important that the undersides of the leaves be kept well covered with bordeaux because it is there that the leafhoppers feed.

Spraying potatoes with bordeaux mixture is a form of insurance in which every potato grower can afford to invest. It pays annual dividends of increased yields. During wet seasons bordeaux mixture

saves the crop from the ravages of late blight, while in dry seasons it turns the tables on hopperburn.

The above recommendations should be supplemented by thorough eradication of weeds in and surrounding the potato field since such plants harbor the insects.

Arsenical Injury.—Too Much, or Improperly Applied Paris Green, Arsenate of Lead, etc.

The signs:

Dead spots frequently appear on the leaflets, usually starting from wounds (insect injuries.) (Fig. 8.) These spots greatly resemble early blight. Residue from heavy dosage with paris green or lead arsenate is present on leaves and stalks.

Frequently dead tips of growing shoots are to be found associated with heavy accumulation of poison at the leaf axils.

Dead areas may occur on exposed stems, the dead surface showing a metallic luster.

Fig. 8. Arsenical injury. The holes in the leaflets were made by the flea beetle and the arsenic injury followed.

Diseases Controlled by the Treatment of Seed Tubers

POTATO SCAB

Economic importance:

This disease each year causes enormous losses which are in general overlooked. In many fields, five per cent of the tubers are too scabby to be picked up at all; five per cent or more may be rejected at the car door. A noticeable amount of scab makes potatoes unfit for marketing under the new government grades. At the great markets un-

Fig. 9. Potato scab.

graded potatoes are sorted again before bagging. Here five per cent more become culls. The farmer may not know that he is standing this loss, but it is reflected in the price paid him for the low-grade product. It is safe to say that the Michigan crop shrinks from 5 to 10 per cent, year in and year out, because of scab.

Scabby seed gives a poor stand and a poor crop of scabby, and in part, at least, of deformed, small tubers.

Signs of the disease:

These are well shown by the illustration. (Fig. 9.) Often the individual scab spots merge, making the entire potato roughened and worthless.*

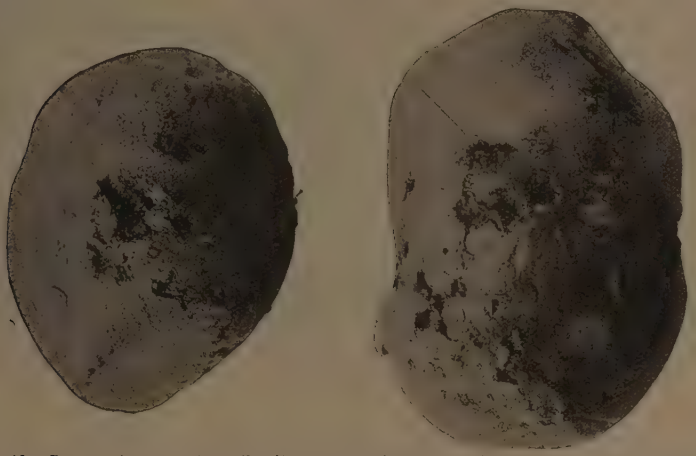


Fig. 10. Deep scab caused by soil mites. The animals work in the lesions caused by scab.

Cause:

An organism, *Actinomyces scabies* (Thax.) Güssow, is the cause of this disease. This organism was formerly classified as a low form of fungus and under the name *Oospora scabies* Thaxter.

Life history of the causal organism:

In spite of the many theories as to the origin of potato scab, it is now generally recognized that a specific parasite is responsible for the disease. The organism belongs to a group that is common in all soils, especially those in which plenty of organic matter is decaying. It is likely a wide range of plants is attacked by the same organism, but so far, the disease is recognized only upon the radish, sugar beet and the potato.

Scab spots harbor the bacteria. These germs may be seen at digging time as a white or grayish film on moist scab spots. The film consists of threads of the bacteria which break up into small parts, each of which is capable of starting a growth of the organism.

The organisms which produce the scabbiness exist naturally in our soils of alkaline reaction. With such soils, seed treatment does not prevent scab. But the greater part of Michigan's potato crop is produced on slightly acid soils which are not naturally infested with the scab organisms. With the acid soils the organisms which come from the

*Frequently Deep Scab occurs. This is the work of soil mites (small spider-like animals) which may attack at a scab spot or directly through the tender skin of the tuber. (Fig. 10.)

Fig. 11. Crop grown from scabby tubers, untreated. Same size plot as Fig. 12. Sorted into grades—Small scabby, small not scabby, large scabby, marketable. Note low yield of marketable tubers and that practically half the yield was scabby.

Fig. 12. Potato scab and scurf controlled. Yield from potatoes soaked one-half hour in Corrosive Sublimate, 4 oz. to 30 gallons of water. This plot showed only four scabby tubers and less than 4 per cent Rhizoctonia.*

*Taken from: G. H. Coons, Seed tuber treatments of potatoes. Phytopathology 8:457-468, 1918.

scabby tubers are the greatest source of danger to the next crop. When a scabby tuber is planted this furnishes virulently infectious material for the new tubers. It is, of course, evident that the germs may drop from the scabby tubers upon sound tubers, hence apparently clean tubers may carry the germs to the field. Clean or disinfected tubers put in old potato sacks or crates may become contaminated with germs. Seasonal variation in prevalence of scab seems to be associated with soil temperature and soil moisture variation, scab being most severe under hot, dry conditions.

Control:

The following specific directions for control may be given:

Rotate the potato crop as a sanitary measure to prevent the soil from becoming heavily infested with the virulent strains of the scab germ.

Potatoes do well on fairly acid soil.

With certain soils in areas near large cities where soil has become infested with the scab organism, the use of commercial sulphur at the rate of about 400 pounds to the acre will doubtless be of benefit in giving a marketable crop. With limestone soils, it does not seem possible to change the reaction of soils sufficiently with sulphur applications.

Heavy liming of the soil seems to increase the amount of scab. Lime should follow the potato crop rather than precede it.

Scabby tubers are culls and should be sorted out. Plant only smooth sound seed-stock. The culls may be used for stock food. When corn is worth 80 cents a bushel, potatoes are worth about 20 cents for feed purposes.

Disinfect all tubers planted as directed under "Seed treatment" on page 50. (Figs. 11 and 12.)

THE RHIZOCTONIA DISEASE. "BLACK SCURF."

(Also Called Little Potato and Rosette)

Economic importance:

This is a very serious disease on poorly drained or "crusty" soils. It is the usual cause of poor stands, especially in wet years and in the wet portions of fields. In its effects on the tubers it is more or less disfiguring, since tubers showing "black scurf" are not first class stock.

A severe form of loss comes from the effect of the disease upon plants forming tubers. Affected plants make a rank growth of tops but set a great number of small, misshapen, unmarketable tubers. From 10 to 25 per cent of the plants of a field may be affected. This disease is so serious that the farmer can neither afford to overlook its injuries nor neglect the control measures recommended.

Signs—On the tubers:

Irregular, purple-black lumps, "black scurfs," about one-sixteenth to one-eighth inch in diameter are formed on the tubers. (Fig. 13.) These

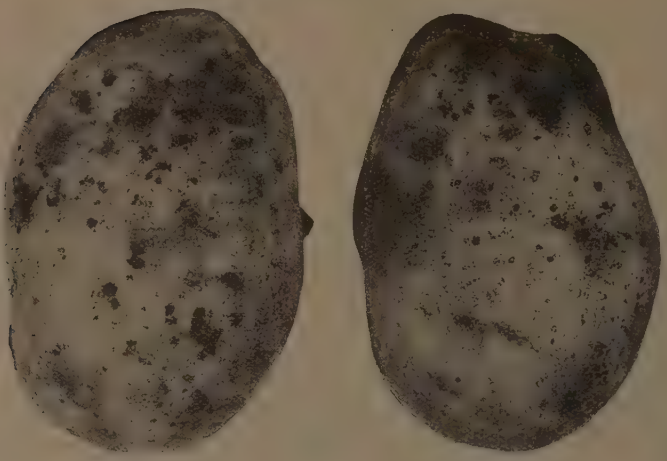


Fig. 13. Black scurf or Rhizoctonia. Note purple-black lumps on surface of tuber.

Fig. 14. Aerial tubers caused by the girdling of the stems by black scurf.

look like bits of dirt clinging to the skin, but they do not wash off. When wet, they no longer appear dirt-like, but stand out as black specks on the brown skin of the potato. Sometimes a black, russet-like scab spot is produced when the attack is severe enough to injure the skin.

Fig. 15. Effect of black scurf on the growing sprouts. Note that when the tip rots the plant may start again from below the rotted portion. This leads to a weak, backward hill.

On the sprouts and stems:

The disease shows upon the young stems as reddish brown, sunken cankers which may be severe enough to cause a rotting of the sprout. Blank places in the field result from the rotting of the tip of the sprout before it gets above the ground. (Fig. 15.) Weak plants which lag a month or so behind the healthy plants are the result of the rotting off of the shoot and the starting of secondary sprouts from beneath the rotted tip.

On the older plants which have been less severely attacked the early part of the season, cankering and girdling of the underground part of the stem may take place. This girdling severely injuries the stem, killing and rotting the bark. Since the food stored in the tuber moves from the leaves in this bark, the girdling interferes with normal tuber formation. This leads to a setting of tubers above the girdled portion and accordingly near the surface of the ground. The tubers thus formed are small and worthless. Often tubers form above ground in the axils of the leaves. (Fig. 14.) The girlding effect of the fungus on stolons, also, affects the setting of tubers in cases where the main stems are not so severely attacked.

The cause:

A parasitic fungus called *Rhizoctonia solani* in its pathogenic stage and *Corticium vagum solani* Burt in its fruiting stage is the cause of this disease.

Life history:

The Rhizoctonia fungus exists naturally in forest soils. With continued agriculture, by growing of small grains, and by drainage, the soil infestation in ordinary land drops until not more than 10 per cent, on the average, of infection of the tubers arises from a soil source with ordinary potato land.

Although this fungus, like the scab organism, is now to be found in many soils, the strains vary greatly in virulence and the amount of soil infestation varies. The chief sources of infection to the sprouts are the resting bodies found on the tubers, especially those near the eyes. These resting bodies are merely clumps of fungous threads which carry the fungus over winter. The organism grows out from these clumps in the form of white or slightly brownish threads, which reach the sprouts and bore into them when conditions are favorable for infection. This attack leads to the stem cankers and the rotting of sprouts already described.

In July or August the fungus produces its fruiting bodies about the stems and on the soil about diseased plants. This stage consists of a whitish growth which makes the stem look ashy or mealy. (Fig. 16.) The part the spores thus produced play in the distribution of the fungus and in the production of disease is not known.

With the onset of cool weather the fungus produces its resting bodies on the tubers and this stage plays the most important role in starting the fungus year after year.

Control:

It is clear from the above discussion that the soil and the tubers are the important sources of the fungus and of these the tubers are the more dangerous. The soil may be kept free from serious infestation by the rotation of crops. There is some reason to believe that to follow potatoes with sugar beets, or vice-versa, augments disease. Grain crops are but little attacked by this disease.

Early digging of potatoes avoids much of the deposit of black resting-bodies.

Two forms of treatment are available, the one using formaldehyde and the other corrosive sublimate (mercury bichloride) solution.

Fig. 16. The fruiting stage of the black scurf fungus.

If formaldehyde is used, the seed stock must be sorted closely to remove every tuber showing black resting bodies, "black scurf." An outline for the treatments is given on page 50.

The close sorting required in the formaldehyde treatment is not required with the use of the corrosive sublimate. The reason for this is as follows: Formaldehyde does not kill the threads of the fungus within the lumps and disappearing by evaporation or absorption by the soil, allows the fungus to sprout from within the resting body. On the other hand corrosive sublimate is lasting in its effects upon the resting bodies and exhibits an antiseptic effect preventing the growth of the fungus.

FUSARIUM WILT

Economic importance:

This disease is found throughout a wide area of the United States. Probably all crops of potatoes grown on sandy land and in a hot growing season are more or less affected. The losses come chiefly from shortening of the crop due to early death of diseased plants.

Signs—The field aspect:

The death of affected plants occurs long before frost. The dying here and there of hills, commonly ascribed to admixture of early varieties, is usually due to this disease. Sprayed potatoes, free from the wilt, will stay green, growing and producing a crop, until killed by frost.

Upon the growing plant:

In early stages the plant shows rolled or slightly wilted foliage. Frequently the color is of lighter shade. One stalk in a hill or several may be affected. This is followed in the course of a few days by the withering and drying up of affected portions. (Fig. 17.) The woody parts of affected stems are brown when cut across and show a brown

Fig. 17. Plant killed by Fusarium wilt. (*Photo by Roy Nelson.*)

stain which is due to the activity of the parasite. The pith often shows brown flecking.

Upon the tubers:

The fungus in the stem gets into the tubers by growing from the mother plant along the tuber stem. With the killing of the roots by Rhizoctonia or by drought, etc., the fungus from the soil may also enter the plant. The disease is best diagnosed by cutting a thin slice from the butt or stem end of the potato tuber. (Fig. 18.) Invasion of the tuber is shown by a yellowing or dark staining of the vascular ring which may be evident only a short distance into the tuber—one-fourth to three-fourths of an inch. Under warm storage conditions infection is commonly found to have progressed one inch or more into the tubers. The color of the water tubes becomes brown or black as the fungus progresses into the tuber.

Cause of the disease:

A parasitic fungus, *Fusarium oxysporum* Schlect.

Course of the disease:

The fungus probably occurs naturally in all sandy soils. Isolations from Michigan soils which had never grown potatoes yielded the organism. It has been isolated similarly from virgin soils in other states. Evidence points to frequent cropping with potatoes intensifying the infestation by the parasite. Potatoes grown in gardens frequently show a high percentage of wilt. The fungus is also carried to the field in the seed tuber.

Both sources of infection are important. Primary infection which takes place from the fungus naturally occurring in the soil, doubtless occurs through the fine feeding roots. While sound roots may be attacked it seems likely that the chief infection results from roots wounded or killed by attacks of disease such as Rhizoctonia or scab, or from the roots near the surface of the soil which are killed by drought, cultivation, etc. Wilting from such a type of infection occurs either late in the season or perhaps not at all. A uniform dying of plants in a field late in the season, accompanied by uniform infesta-

Fig. 18. The signs of Fusarium wilt—blackening of the water-tube ring in the butt end of the affected plants.

tion of tubers can be best explained by the hypothesis that root infection occurred, doubtless in the roots near the surface of the ground which have been killed by the drying of the soil. Tubers from plants so affected show discoloration of the water tube system due to the fungus harbored there.

A second type of infection comes about from the planting of diseased tubers. The fungus in the seed piece readily grows into the sprout and produces its effects early in the season. This leads to the severest form of the trouble and in it the plants wilt and die when the tubers are only half grown. Tubers from such wilted plants are commonly about the size of a hen's egg and have pointed ends. They also harbor the Fusarium fungus. The planting of small, whole potatoes directly from the bin serves to load the seed stock with the diseases such as this one which lead to the production of small potatoes. If small potatoes are to be planted, it must be known that they are from vigorous hills.

In either type of infection, the fungus invades the water tubes of the plant and lives there and gives off its poisonous by-products. Wilting probably comes about from poisoning of the plant rather than actual stoppage of water supply.

The fungus grows into the tubers from the affected stems. Immature plants frequently show some tubers into which the fungus has not yet grown. The fungus has not been known to fruit in or upon the growing plant in the field. It doubtless fruits in the soil.

It should be borne in mind that other factors, such as climatic conditions, bring about somewhat similar vascular discolorations. These are commonly confused with true wilt.

Control:

Any set of control measures should recognize the two sources of infection. Ultimate control only can come from varieties resistant to the disease. These, as yet, have not been developed. The control measures suggested will do much to cut down loss.

Avoid unnecessary wounding of the roots of growing plants.

Rotation of crops is necessary.

Infected tubers should be stored under dry, cold conditions to prevent rotting in storage and to prevent excessive advance of the fungus into the tubers.

Since the most serious effects come from planting tubers harboring fungus, it is necessary to attempt to rid the tuber of this infestation. Since the fungus lives in the butt end of the potatoes, this can best be done by consistent rejection of all butt-end pieces. Comparison of stem end with "rose" end pieces where the stock was infected with wilt has shown the superiority of the rose end pieces. Tubers for planting should be cut by hand after the usual disinfection. The first cut should remove one-half to one inch of the butt or stem end. This should be rejected. If the tuber so cut shows no flesh discolorations then cut for seed in the usual manner; if the flesh is stained or discolored, reject the whole tuber. This method does much to free a seed stock from the infection which leads to the severe forms of wilt.

BLACK LEG

Economic importance:

This disease is wide-spread in the Upper Peninsula. Before the summer of 1917, it had been reported in a few localities from the Lower Peninsula, and then chiefly in potatoes imported from northern localities. The disease was known to cause 25 to 75 per cent loss in certain fields in 1915. In the wholesale shipping of tubers into the state which took place in the spring of 1917, to supply seed stock, black leg was introduced into a great number of southern counties. The disease persists for years in a seed unless consistent control measures are employed. It is the cause of serious rotting of tubers in storage. Black leg is a dangerous, unnecessary disease.

Signs—On the young plants:

This disease manifests itself by rotting the stem, which softens and turns coal black. The rotting usually extends from tuber to surface of ground and may blacken upper parts of stem. Young and old plants are attacked. Stems of old plants become soft and slippery. (Fig. 19.) The leaves roll, then wilt and turn bright yellow. The primary effects are evidently due to poisoning by the germs.

On the tubers:

Tubers rot, usually from stem-end inward, with a black rot, in which, commonly, canals or rotted pits lined with a creamy bacterial slime, occur. (Fig. 20.)

Cause:

A bacterial organism, *Bacillus phytophthorus* Appel.

The course of the disease:

The germs are carried to the field in tubers which grew on plants in which black leg disease developed but slightly or late in the season. Bruised or wounded tubers are also believed to harbor the germs. Affected tubers, when planted, rot in the ground and communicate the disease to the sprouts. The black leg germ, with favorable soil conditions, may kill the young plant before the end of the first month, or, the disease may progress very slowly. The disease has been observed to spread widely in a field during a wet season. How the causal organism is carried from plant to plant is not known, but it may be that the insects which infest rotted tissue or the washing of water from plant to plant are the agencies. Cultivation may be a means. Slightly affected plants or those in which the disease develops late in the season show tubers with the vascular system discolored and sometimes soft rotted. The germs pass from crop to crop in such tubers and also in those wounded or bruised tubers inoculated by contact with infectious matter in the soil or store house.

Fig. 19. Black leg on young plants. Note the blackening and rotting of the stems of the affected plants.

Control:

It is not known for Michigan conditions whether the germs live over winter in soil which has borne a diseased crop. The rotation which is necessary for other reasons will eliminate danger from this score.

Sound seed tubers, free from rot, wounds, bruises, scab, or other blemish, disinfected in either formaldehyde or corrosive sublimate, will give a crop practically free from black leg. In the season of 1915, observations which were made in the Upper Peninsula showed that seed tubers carefully sorted and treated, gave less than one-tenth of one per cent of black leg. Unselected seed tubers from the same car, planted without treatment gave a field with 75 per cent black leg.

Black leg plants (including such tubers as are formed) wherever found in the field, should be carefully pulled, carried from the field and destroyed. This keeps the diseased tubers out of the seed stock.

Fig. 20. Tubers rotted by black leg bacteria. Note blackening and tendency toward canal formation. The glistening mass is the slimy bacterial growth.

Diseases Controlled by Use of High Grade Seed Stock

LEAF ROLL

This disease is a very serious menace to the potato grower. Certain lots of seed may show a striking amount of disease. Fields showing 50 to 100 per cent leaf roll have been reported. One variety grown at the College showed every plant in the row diseased. Failure of the crop in certain noted potato-producing sections has been attributed to leaf roll.

Signs—On the leaves:

These are usually shown by the permanently rolled (that is not unrolling with wet weather, etc.), leaflets usually light, greenish-yellow, which in typical cases may be bronzed or reddened. (Fig. 21.) The leaflets of the lower leaves are most characteristic. These, particularly the terminal ones, take on a spoon-shaped appearance due to the upturning of the tips. They have a leathery texture and crackle and rustle when brushed against. When bent, they break with a very audible snap, indicating their brittleness. Such leaves may show a great number of black dots scattered over the leaflets. The leaves may be bronzed or they may, in some cases, remain nearly normal. Leaves from leaf roll plants do not wilt so readily as healthy leaves.

General appearance:

In severe cases the affected plants are sharply set off from the healthy broad-leaved, deep-green plants. The furled leaflets are sometimes found in both young and old leaves, the unhealthy color and the dwarfing in the last stages are characteristic.

On the tubers:

The tubers borne on diseased plants are frequently set close to the stems, although seasonal effects are also known to produce similar close setting with some varieties. Many tubers from leaf roll plants show blackening of the fibers and produce only weak, spindling sprouts. The seed piece is often found firm and crisp, even as late as at digging time. The tubers on diseased plants are small and what was said under "Fusarium wilt" about planting small tubers indiscriminately from the pit or cellar, applies with particular force here.

The cause of the disease:

The cause of this potato disease is unknown. It is known that the disease is infectious and caused by a virus which infects the growing plants and which is carried year after year in the seed. This virus is spread from plant to plant by aphids.

Fig. 21. Photo leaf roll. The lower leaves stiff, slightly rolled and upturned at the tip. Upper leaves erect, often furled. Upper plant, early stage; lower plant, later stage.

The control:

Without definite knowledge of the cause of the diseases of this type it is evident that control measures to be proposed must be of a general nature. It is advisable that farmers learn to recognize these deviations from the normal and that they make strong effort to eradicate such diseased plants from the field to be used as a source of seed stock.

Whether the farmer actually learns to recognize each particular type of disorder is not important, but it is important that, in general, seed stock be procured from high-yielding hills. This means that the farmer should have a seed plot and go over this field several times during the summer, pulling out all weak hills and getting rid of all plants of the undesired varieties. Then the plants should be dug by hand and only those hills saved for seed that show a high yield and proper type.

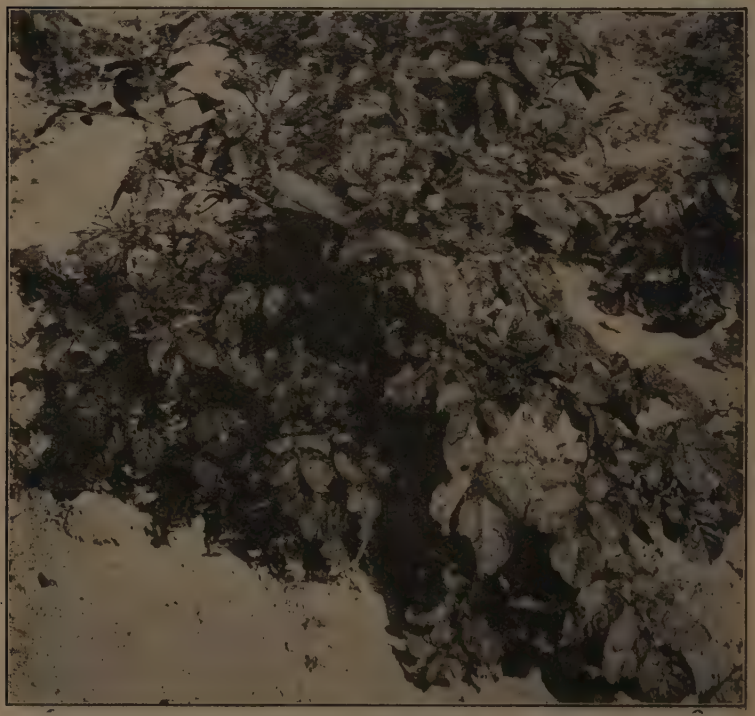


Fig. 22. Potato mosaic.

MOSAIC

Green Mountain, Bliss Triumph, and some other varieties frequently show peculiar down-turned leaflets in which the veins stand out prominently. (Fig. 22.) The disease is less common, or at least less noticeable, on the Rural group of potatoes. Diseased leaflets are mottled with patches of light green, giving rise to the name applied to this malady. This mottling becomes masked in dry, hot weather which makes diagnosis of mosaic difficult. Observations made in 1915 seemed to indicate the disease is infectious, probably transmitted by aphids. Since, that time aphids have been definitely shown to be active agents in the transfer of the virus. It is certain that tubers from affected hills reproduce the disease the next year. The disease is known to reduce the yields of fields strongly, some affected fields yielding only 70 or 80 bushels in years when healthy fields under the same conditions yielded 200 bushels. Even with mild mosaic on Green Mountain potatoes, reduction of yield amounting to 35 bushels per acre was demonstrated.* The farmer must recognize this disease in order to avoid using tubers from affected hills for seed purposes. Mosaic plants occurring here and there in a field should be pulled out and destroyed in order that they may not be sources of infection. Aphid control is important. Seed stocks as free from mosaic as possible should be sought.

STREAK

Streak is perhaps the most active of the group of diseases associated with the "running out" of potato seed stock. So rapidly does degeneration follow in the wake of this disease that in two seasons after infection takes place the tubers are too small to plant. Although reported as serious in some of the European countries, streak in Michigan is almost self-eliminating and is more of scientific interest than of commercial importance.

Primary symptoms occur on full grown plants during the latter part of the growing season and are recognized by brown streaks, one-tenth to one-fourth of an inch long, which occur on the veins of the leaflets. The streaking is more evident on the lower side than the upper side of the leaves. As the disease progresses the leaves become yellow and wilt. Brittleness of the leaf petioles and stripping of the leaves from the stems are symptoms characteristic of the streak disease. The first symptoms are noticed on the upper part of the plant but the disease progresses downward rapidly and under favorable conditions all of the leaves except the terminal ones become involved. Within a week after the first symptoms are noted on an apparently normal and vigorous plant all of the leaves except the top ones maye be stripped off giving the plants a "palm tree" effect. The reduction in yield of tubers the first season is slight.

Secondary symptoms appear when tubers from plants affected with

*Kotila, J. E., Mosaic and potato yields in Michigan. Michigan Sta. Quarterly Bul. 5:188-189, 1923.

primary symptoms of streak are planted. The course of the disease is reversed and it progresses upward instead of downward as is the case when nearly mature plants become infected late in the season. The bottom leaves are first affected, turn yellow and drop from the stems. More and more leaves become affected and finally only the terminal ones remain. (Fig. 23.)

Fig. 23. Streak. "Palm tree effect." Note dying of lower leaves. These break off easily and then cling loosely to the stem.

Only dwarf plants are produced the second season and few, if any, of the tubers reach marketable size. Consequently very few of them are planted the following season.

It is believed that the disease is of the virus type and is spread by aphids as is the case of leaf roll and mosaic.

Roguing out diseased hills and thus eliminating sources of infection is recommended as a control measure for this disease.

Other Virus Diseases of Potato

As a result of intensive observation by many plant pathologists a great many potato diseases of similar type have been distinguished. These diseases are known by various names and for the most part information consists merely in field notes on occurrence. Nothing is known as to the cause of diseases of this type, although it is commonly assumed that they are of the same nature as mosaic and are caused by a virus, presumably carried over from year to year in the tubers and spread in the field by aphids.

A few diseases of the virus type such as leaf roll, mosaic and streak have been more fully studied while others merit much more study before suggestions can be made concerning them. The following brief notes will record the existence of these diseases in Michigan fields and state their most striking characters:

GIANT HILL

In this disease which is common on Russet Rurals, but known for some other varieties, the plants grow much larger than normal and

Fig. 24. Giant hill (right) with normal hill for comparison (left). Plants gathered after heavy frost, note great frost resistance of giant plant. Note also off-type tubers.

produce a coarse, rough foliage. Blossoms are more numerous and the blooming period is much longer on giant hills than on normal vines. The tubers are large and off-type. The vines stay green long after the other plants have died. It has been claimed that giant hill tubers when grown the next season develop into leaf roll and it may be that this disease is merely first stage leaf roll. (Fig. 24.)

RUGOSE LEAF

In this disease, which is also common on Russet Rurals, the leaves become markedly corrugated and roughened, contrasting strongly with the normal foliage. Tubers from such plants frequently produce a progeny which show mosaic symptoms and this disease may be merely a form of mosaic.

DWARFS

Dwarf hills in potato fields are indications of "running out" of the seed tubers. As high as 10 per cent of the hills in commercial fields have been known to show dwarfs.

Signs:

Affected plants show down-curled leaves whose leaflets give a shirred or ruffled appearance to the plant. The stems are much shortened and the plants dwarfed. The tubers are small. (Fig. 25.)

Fig. 25. Mosaic Dwarf. (a) Bliss Triumph plant showing wrinkled, shirred foliage. (b) Same plant a month later.

Cause:

The cause of this trouble is unknown. In some cases, curly dwarf may be the final stage of mosaic or of leaf roll and mosaic combined. The grower first notices a weak hill, dwarfed and slow growing. Tubers from such hills produce a progeny still more diseased. Eventually the tubers produced are too small to be harvested. Early frosts or severe droughts probably do much to eliminate such weakening diseases from the field, since growth is checked before tuber formation has proceeded very far.

Control:

See leaf roll.

Witches' Broom. (Spindling Sprout.)

In this trouble the number of shoots arising from the seed piece is increased enormously, as many as a hundred fine, wiry sprouts developing from the main outgrowths. (Fig. 26.) The leaves on such shoots remain small. The plant, in severe cases, forms a dense mat, losing all appearance of a normal potato plant and appearing like a mat of chickweed.

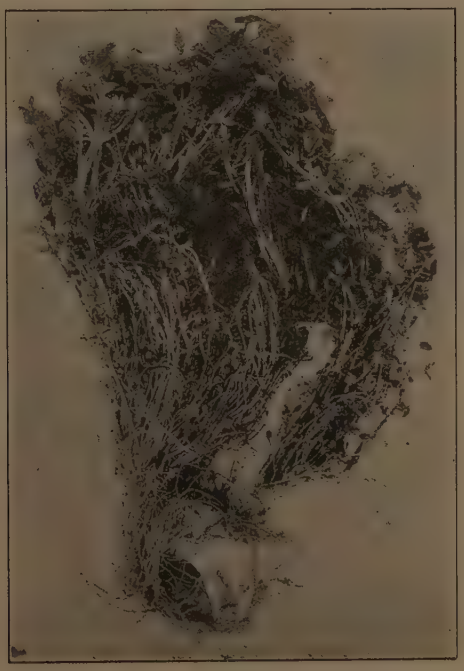


Fig. 26. Witches' broom of potato.

Small tubers, sometimes no larger than a peanut, are produced. The disease can thus quickly be eliminated from the seed stock if care in seed selection be taken.

A disease which leads to excessive bud development and bud growth produces what is called a witches' broom. These are known for many plants, but the fundamental cause which brings about the excessive and premature shoot production has not been discovered. As yet this disease has not produced loss in commercial plantings.

Spindling Sprout

Growers frequently notice that sprouts from some tubers instead of being strong and vigorous are weak and thread-like. This condition has been noticed chiefly in potatoes before they were planted and tests of such tubers have shown a correlation of this condition with leaf roll. It is safe to say that leaf roll potatoes commonly develop weak sprouts. (Fig. 27.)

Fig. 27. "Spindling sprout," (at left) in comparison with normal. Weak germination like this usually indicates leaf roll.

Certain plants in the field may develop a great number of small wiry shoots. (Fig. 28.) This may lead to a bushiness of the plants or even a witches' broom production. Usually such plants have heart-shaped leaflets on the leaves. Such a condition has been called spindling sprout by some. Perhaps the two conditions are related, but experimental work is lacking. Spindling sprout tubers produce weak plants and worthless hills and should be eliminated from seed stock. It would seem very probable that the disease is infectious.

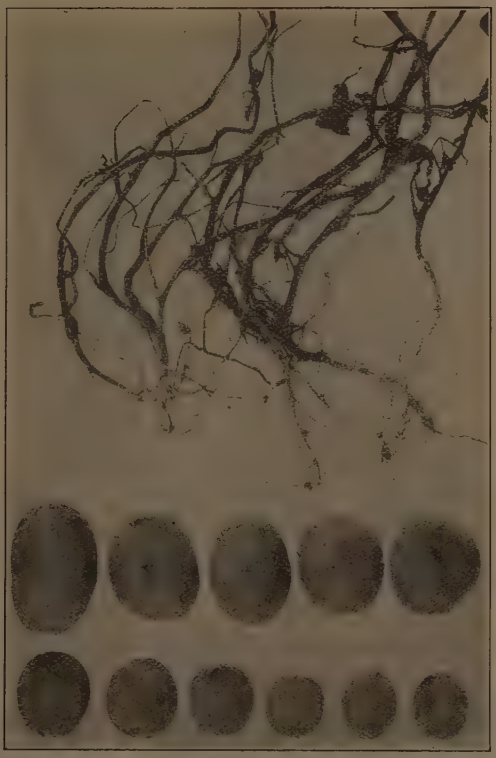


Fig. 28. Spindling sprout or bushiness. Note the excessive number of weak shoots and the general weak growth. Such plants frequently have heart-shaped leaves.

Spindle Tuber

This disease, as the name indicates, causes malformation of the tubers. These are small sized and pointed especially at the stem end. (Fig. 29.) The stems of affected plants are slightly more slender than normal and the growth more upright. The disease is known to be infectious.

Spinach Leaf

Another disease of this type is known by the above name because of the characteristic shape of the leaf. Very little is known of this disease —whether it is a distinct disease or combination of other known diseases.

In general, growers must have in mind the ideal of the normal healthy hill and in developing fields for seed purposes, rogue out all aberrant types.

Fig. 29. Spindle tuber. Note the small, pointed tubers.

OTHER DISEASES OF THE POTATO

Fusarium Dry Rots

Sometimes in years when late blight is not a factor, dry rotting of the tuber occurs. (Fig. 30.) This puzzles the farmer who is not always able to distinguish between the various kinds of rotting which occur on the potato. Late blight rot is commonly seen at digging time or immediately after the tubers are put in the storage cellar. Beginning then, it develops throughout the storage period. The Fusarium rots, on the other hand, under Michigan conditions, do their greatest damage during the latter part of the storage period, and are associated with warm, humid storage conditions and with bruising or wounding of the tubers. Tubers dug when so immature that the skins break easily, suffer loss from the Fusarium dry rot. The great loss which occurs in the "new" potatoes shipped in from the South, comes about from this sort of trouble.

The rot produced is at the outset firm and cheesy, unless the tuber has been under very moist conditions. The causal fungus often fruits upon the surface of the rotted portion, producing white or pinkish tufts of mold. Eventually the tuber shrivels and dries to a hard mass.

Fig. 30. Fusarium rot showing typical dry rot.

Fig. 31. Fusarium rot following wounds. (*Photo by Ray Nelson.*)

When partially rotted tubers are used for planting, the seed pieces are apt to rot in the ground before the sprout is established.

The cause and control of the disease:

The disease of the potato arises from the attack upon the tuber by various fungi of the Fusarium genus—a group of organisms widely distributed in soils and found naturally on the potato tuber. Under ordinary conditions the tuber remains free from the trouble, but if the skin be broken, if the tuber be wounded, or if the Fusarium wilt fungus has penetrated deeply, rotting is apt to take place providing that storage conditions are favorable for the growth of the rot organism. (Fig. 31.)

The necessary control measures are clear from the above statement. If tubers are dug after the skins have become tough and if better care is used in handling, the bulk of this loss can be eliminated. In the various farm operations, in loading potatoes into cars and in running the potatoes into cellars with chutes, etc., the danger from bruising the skin of the potato must be recognized, if the loss from this cause is to be avoided.

Fig. 32. Rot caused by the honey mushroom. The thread-like bodies are the fungous growths.

Rot Caused by the Honey Mushroom, *Armillaria mellea*

Sometimes when a potato crop is planted on newly cleared land where the rotted roots and stumps have not been carefully removed, hills are found showing rotted tubers. One case has come to our attention where the loss was nearly 100 per cent.

The disease results from the attack of a parasitic mushroom which is well known as a cause of rot of the roots of forest trees and whose threads growing through the soil have met with the potato tubers. Affected plants wilt and die, the stems showing the rhizomorphs of the attacking fungus.

The honey mushroom injury can be recognized by the string or root-like masses of these fungous threads. (Fig. 32.) The mushroom itself seldom develops in the summer, although it can be found in the fall about the bases of stumps. (Fig. 33.)

Fig. 33. The honey mushroom (*Armillaria mellea*) is commonly found on rotting stumps and roots.

The rot caused is more of a curiosity than a serious loss and need not deter anyone from utilizing newly cleared or partially stumped land for potatoes.

Hollow Heart

In years of uneven rainfall when large potatoes occur commonly in the hills, many of these show clefts at the heart. (Fig. 34.) In such potatoes the flesh has split leaving a lens-shaped hole. The lining of this cavity becomes brown, just as the cut flesh of a potato turns brown when exposed to the air.

Certain varieties more than others tend to the production of extra large tubers. Since such tubers are in disfavor with the trade, and under the government grades are not considered sound potatoes, it is necessary with such varieties to plant closer in order that by slight

Fig. 34. Hollow heart.

crowding this tendency to produce large tubers can be overcome. It is evident also that the evenness of moisture supply which comes from good drainage and from frequent cultivation will have a beneficial effect in preventing this trouble. Preventive measures for this trouble must be sought in improved methods of culture.

Internal Brown Spot

During drought years potatoes often show rusty flecks throughout the flesh. (Fig. 35.) This is not caused by a parasite, but seems wholly a reaction to some unfavorable growth condition. Such tubers when planted do not transmit the disease, but it is doubtful if it is advisable to use them for seed purposes. As is advised on page 51 the farmer should reject for seed purposes all tubers showing discoloration of the flesh.

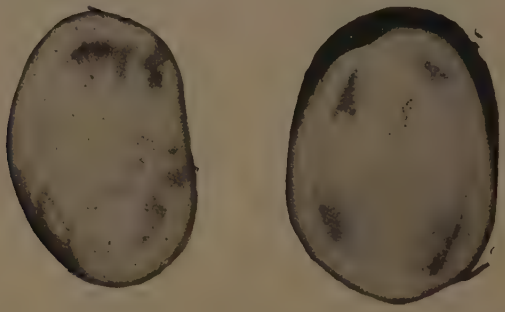


Fig. 35. Internal brown spot. Rusty flecks occur in the flesh.

Frost Injury to Potato Tubers

When potatoes freeze in the ground, they often show rotting of the frozen portions which resembles in part the various rots of the tubers previously described. Such injuries must be carefully distinguished. It sometimes happens that the tubers, when loaded, show only the shrinking and wizening which comes from freezing and they rot later in the course of shipment. (Fig. 36.) Such cases of "field frost" may

Fig. 36. The end of the potato was frozen and rotted. The white masses of fungous tufts developing on the decayed tissue.

readily be distinguished from injury received in transit through position of the potatoes in the car, etc. Field frost will be distributed throughout the car, while freezing in transit occurs at the more exposed portions.

Another form of injury which comes from exposure to cold, especially from prolonged chilling at temperatures near the freezing point, shows as blackening of the fibrils of the potato, especially at the stem end. (Fig. 37.) This blackening resembles the disease described as net necrosis,* which is found in the field before frost occurs. The type induced by chilling may be provisionally called frost necrosis. Usually with this form of injury the tissue shrinks slightly, indicating clearly the relation to the chilling. In other cases, the netting of the tuber is the only sign and this is evident only upon cutting. With net necrosis, the netting extends to the center of the tuber or beyond,

*Net Necrosis was described a few years ago as a disease found early in the fields, where freezing was not a factor, in which the tubers showed blackened fibrils all through the flesh. (Fig. 38.) Sections through the tuber at almost any part show the diseased condition, although it is more evident at the stem end. The blackened flesh is free from bacteria and fungi and the disease is believed to be related to leaf roll.

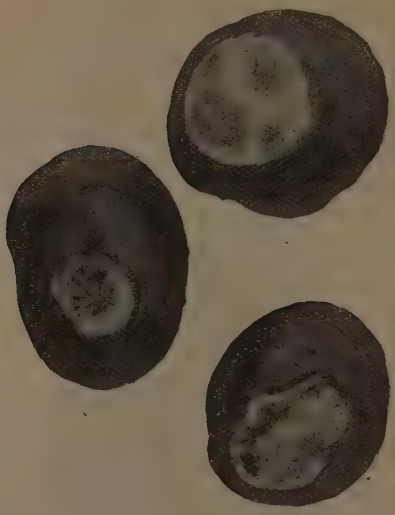


Fig. 37. Frost necrosis due to chilling in the field.

while with frost necrosis, the injury is local. Lightly frosted tubers often show brown or grayish-black areas in the flesh at the stem end, just outside the vascular system and under the skin about an eighth of an inch. (Fig. 39.) The flesh is somewhat withered at these places. Such tubers blacken when cooked.

Fig. 38. Net necrosis. All the fibers of the tuber from the stem end to the tip are blackened.

Breakdown

Breakdown of potato tubers is another trouble which occurs during the storage season and which causes a shrinkage of thousands of bushels each year. The injury was particularly evident in Michigan

storage houses during the 1922-23 season. Due to the bumper potato crop in 1922 and the low prices which prevailed during the fall, many growers held their potatoes hoping for higher prices in the spring. As a result storage houses were overloaded, and even though the temperature may have been kept below 40° Fahrenheit great losses occurred. In one northern Michigan storage house in which 15,000 or 20,000 bushels of potatoes were stored, the loss from breakdown was reported as 33 per cent. On May 24th, 1923, a specimen of breakdown was received from a grower who reported that 25 per cent of his stock was affected. When placed in storage on November 1, 1922, the grower stated the potato tubers were in perfect condition. Similar reports were received from growers in various parts of the state, indicating that losses from breakdown were general and not confined to any one section.

Surface Breakdown:

The first symptoms of breakdown are observed by the grower three or four months after the date the potatoes are stored, when some tubers in the bins show on their surface slightly sunken, round or irregularly-shaped spots varying in size from one-sixteenth to three-fourths of an inch in diameter. (Fig. 40.) The borders of the spots may have

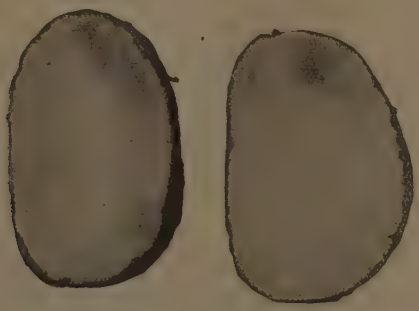


Fig. 39. Blackening or bluing of flesh as a result of chilling.

a bluish or gunmetal hue. Upon cutting through these sunken spots with a knife it is found that they are superficial and except for the thin brown layer of dead cells beneath the skin, no rotting has progressed into the tuber.

The pitting of the tubers becomes more pronounced as the season advances and with the coming of warm weather in the spring the most severe symptoms of breakdown are seen. Many tubers are found to be soft and mushy and others when cut open show black centers, a condition known as "blackheart." (Fig. 41.)

Blackheart:

Breakdown is not caused by a fungous or bacterial parasite as are such diseases as late blight or black leg. The injury is brought about by a lack of oxygen, and the pitting as shown during the winter re-

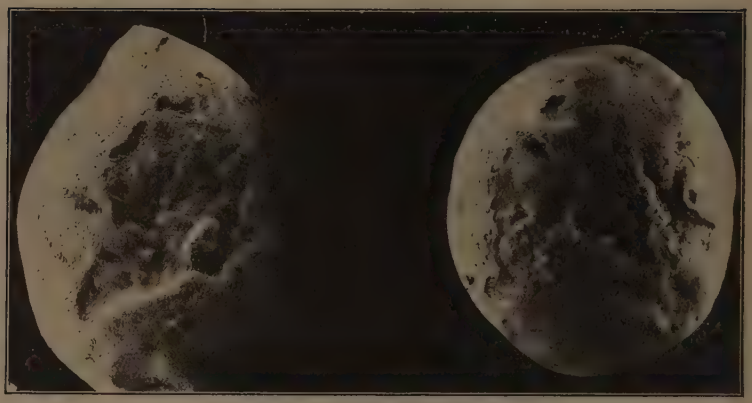


Fig. 40. Surface breakdown.

sults from the death of the cells around the lenticels or breathing pores of the tubers. As more and more cells are killed, the spots increase in size. Potato tubers respire more rapidly in the latter part of the storage season and unless there is a supply of fresh air the cells in the central part of the tubers will suffer from the lack of oxygen and as a result will be killed and blackened as shown in Fig. 41. Such tubers fall prey to saprophytic bacteria, which are present everywhere and which are not able to attack sound potatoes. The bacteria cause the tubers to rot with a very foul odor which makes the sorting over of the stock or the cleaning out of the storage house a disagreeable task.

The enormous losses caused by breakdown each year can be prevented by giving more attention to ventilation in the construction of new potato storage houses or by remedying the defects of those already constructed. The following recommendations are made:

1. Provide each potato cellar or storage house with adequate sized inlets for fresh air and outlets for foul air.
2. Provide false floors and walls for the bins. Slatted flues to rest on the floor from which vertical flues may arise, will also serve to give proper ventilation.
3. Provide air spaces between bins.
4. Never store potatoes in piles more than five feet deep without making some provisions for air to get to the center of the pile.

For more detailed directions in regard to ventilation of potato warehouses reference is made to Michigan Quarterly Bul. Vol. 5, No. 1, Aug. 1922.

Potatoes shipped during the winter when cars have to be heated with stoves sometimes arrive at the market with the tubers near the stove showing an inky black heart. Experiments have shown that tubers heated to 100° F. will develop this trouble, thus fastening the cause on the over-heating which occurs near the stove. It has also been found that this blackening of the heart can take place at much lower temperature if the air supply about the tubers is limited.

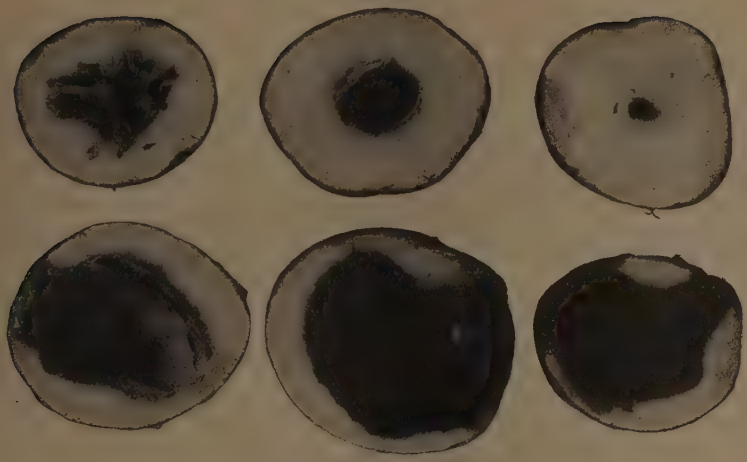


Fig. 41. Black heart.

Occasional losses of this sort have been reported from large pits, and to avoid loss it is advisable that care be taken to provide good ventilation in large pits or other storehouses. The use of refrigerator cars for potatoes should be resorted to early in the season rather than the shipper taking chances with lined, stove-heated cars during severe freezing weather. After cutting of seed tubers, black heart may develop in the cut pieces if the stock heats. If planting does not take place at once, the tubers should be spread out thinly.

Fig. 42. Salt injury.

Salt Injury

It sometimes happens that potatoes next to the floor of cars are found shriveled and the flesh blackened by what appears to be some form of rot. (Fig. 42.) If a section is cut through the potato the blackening will often be found to extend from 1/4 to 1/2 inch or more into the flesh. This injury usually occurs only upon one side of the potato and is found in the potatoes upon the car floor and nowhere else. This is due to the action of the salt on the floor, although the presence of this salt may not be evident due to the mixing with the dirt from the potatoes. Cars that have carried hides, etc. are almost sure to produce such injury unless they are carefully cleaned before loading. As many as fifteen bushels have been discarded from such cars. The injury to the potato is due to the extraction of water from the cells, followed by blackening and death of the tissue. Potatoes should be loaded only in thoroughly clean cars.

Somewhat similar effects may be expected from fertilizer or chemical refuse in cars.

Lightning Injury to Fields

Each year our attention is called to what seems to be a very infectious disease which is destroying the potato plants in a field in ever widening circles. When first discovered the plants are withering away in a small area about five feet in diameter. The stalks are brown

Fig. 43. Lightning injury.

and dead, the leaves remaining green. Eventually the plants with the brown stems fall over. Each day the area seems to enlarge.

The trouble just described is caused by a stroke of lightning. The same type of trouble is known to occur on a number of different plants. In seasons when electrical disturbances are numerous, the cases may be considerable in number. The size of the affected area varies considerably, but in the largest seen, the diameter was 35 feet. In this case the plants were killed in an almost perfectly circular area. The potatoes were not ridged. In the lightning injury illustrated, the affected plants are seen to extend along the ridges outside of what would make up a perfect circle. (Fig. 43.) Perhaps this is associated with water standing in the furrows between the ridges.

The progressive dying of the plants in widening circles may continue for several days after the spot is first noticed and seems to be associated with the varying severity of the effect on the plants subjected to the shock, those nearest the place where the lightning struck being most severely injured.

There is no potato disease of such infectious nature as to render it likely that confusion would arise over this peculiar field symptom. The trouble loses its seemingly infectious character after about a week and the farmer has a bare spot in his field surrounded by healthy plants. The matter should be understood by farmers so that undue alarm need not be felt when such injury occurs in the field.

PROGRAM FOR THE CONTROL OF POTATO DISEASES

The Seed Stock

Control measures for potato diseases consist in the main of removal of diseased plants, selection of strong plants, rotation of crops, seed treatment and spraying. The following outline gives the methods of handling potatoes to produce profitable crops. For the development of strains of potatoes for seed production the special bulletins of the college on the subject should be consulted.

Decide on the variety suited to your soil and to your market.

Learn the characteristics of the vines of this variety and of the tubers.

Secure certified seed* in order to avoid the many diseases now so serious in the ordinary run of farm seed stocks. This certified seed must be treated as recommended. Enough of this certified seed stock should be planted in a field away from general potato field to furnish a seed plot for next year's planting. Special care for disease control should be taken with this seed plot.

In handling this plot, and the main crop if possible, it is recommended that all weak diseased hills be pulled out. This treatment is aimed especially at black leg, leaf roll, and curly dwarf. Learn to know potato diseases as shown in vines and tubers. Here again the extension service of the college will help you.

Dig the hills of the seed plot by hand in order that low-yielding hills of undesirable type may be rejected.

*Lists of certified seed growers may be obtained from the Michigan Agricultural College.

Select high yielding hills of proper type for an "extra select" seed plot.

The increase of the serious diseases of potatoes is so rapid that such special precautions are necessary if a grower is to keep his seed stock from deterioration.

Seed Treatment

Select only sound, desirable tubers for treatment. Scabby, bruised, or partially rotted tubers are unsafe.

Treat seed tubers in the following way:

Corrosive sublimate treatment:

Soak the seed tubers in corrosive sublimate solution for one-half hour. The solution is made with 4 ounces of corrosive sublimate in 30 gallons of *soft* water. This treatment controls scab and black scurf. Reinfection from untreated sacks must be avoided. Disinfect these containers in the treating solution.

Large quantities can most readily be handled in a large vat made of heavy stuff, holding 8 to 12 crates at a time. It is well to make this vat water tight by use of heavy duck lining, painted with some waterproof paint, such as asphaltum. (Fig. 44.) Cement vats are also excellent. The solution becomes weaker with use. It loses strength due to the potatoes taking out more of the chemical than they do of the water. Hard water brings about a weakening of the solution. Sacks and dirt also take up the fungicide, hence potatoes for treatment should be free from dirt and should *not* be treated in sacks.

The addition of one ounce of corrosive sublimate to 30 gallons of solution after each batch is dipped, keeps the treating solution at the proper strength. Where potatoes are fairly clean the addition of one ounce of corrosive sublimate after every other batch is sufficient.*

Experiments completed in 1917 show that treatment for one-half hour is as efficient as the longer soaking (1½ to 2 hours) previously advised.

Points on the Treatment.

Corrosive sublimate crystals or the diluted solution are deadly poisonous. Use precaution and keep this material out of the way of live stock or children.

The crystals dissolve slowly in cold water, but rapidly in hot water.

Treated tubers are not safe to feed to stock.

Corrosive sublimate, as the name indicates, attacks metals. It must not be used in metal tanks.

Potatoes should be uncut when soaked.

Treatment with small lots can be readily given by a use of a barrel, soaking 2 bushels at a time.

Formaldehyde treatment:

If the farmer knows the signs of black scurf on the tubers and if he will consistently reject *all* tubers showing the purple-black masses when cutting, the old formaldehyde treatment, known for a long time for use against scab, may safely be employed.

*For small lots, the corrosive sublimate solution may be used four times and then discarded.

Soak the uncut potatoes for 30 minutes in formaldehyde solution made with one pint of concentrated formaldehyde (36 to 40 per cent) in 30 gallons of water.

Points on this treatment:

The experiments completed in 1917 have shown that 30 minutes is as effective a period as the longer time, (1½ or 2 hours) previously recommended.

This solution does not have the power to prevent the "Black Scurf" from causing infection after the tubers are planted, hence the necessity of close sorting when cutting. Since the "Black Scurfs" are very evident when the tubers are wet, if the cutting is done immediately after treating, this sorting is an easy matter.

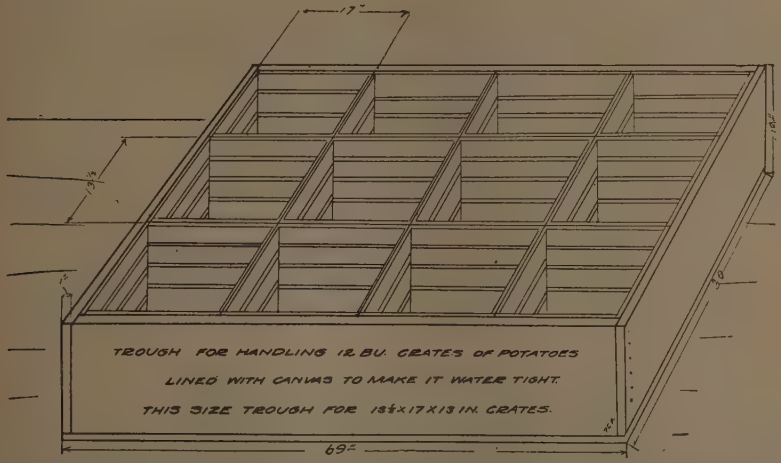


Fig. 44. Diagram illustrating construction of a large vat for use in treating large quantities of potatoes.

The weak formaldehyde solution does not lose strength on standing as is commonly supposed, but it gets slightly stronger. Unlike the corrosive sublimate, it may be used repeatedly for treating.

It is very probable that treated potatoes are not desirable stock food, even when cooked, because of the very injurious effects of even slight amounts of formaldehyde upon digestive processes.

This treatment is about one-third cheaper than the corrosive sublimate treatment.

Formaldehyde is a strong chemical. It is not safe to vary the strengths from those given. Measurement of water may be approximate, the farmer bearing in mind that a large barrel holds 50 gallons. For smaller lots, a large pail, holding 3 gallons, may be used for measuring. Metallic containers may be used with formaldehyde.

Rigid Inspection and Sorting of the Seed Tubers when Cutting

(a) Cut the seed by hand. Do not leave this wholly to hired help. Be on the job and teach the cutters to use only safe seed stock.

(b) Cut off and throw away a slice one-half to one inch thick from

the butt end of each potato. If the water tubes show up as a dark ring, discard the tuber. Any blackening of the flesh is suspicious.

(c) Reject any rotted, scabby, bruised or wounded seed tubers. Cases of Rhizoctonia should be thrown out. If the potatoes have been treated with corrosive sublimate or formaldehyde the rejected potatoes or parts are not safe for stock feeding.

(d) Plant at once. If this is impossible, take care that the potatoes do not heat or decay before planting.

Give the Potato Plant Good Culture

Plant the potatoes on enriched ground—clover or alfalfa sod is best. Have at least a four-year rotation system. The soil must be well drained. Potatoes do well upon and improve slightly acid soil. Give them the best of care. Any set of treatments fails with neglected plants.

Control Leaf Diseases

Spray the plants thoroughly with home-made bordeaux mixture, 4-4-50 beginning when the plants are 3 to 6 inches tall, making at least 5 applications at intervals of 10 days or two weeks.

Use freshly prepared bordeaux mixture prepared as directed on page 55.

Lime sulphur is worthless for potatoes. Commercial bordeaux mixtures have not proved so satisfactory as home made bordeaux. For equivalent strengths of copper they cost about four times more than home-made mixtures. Their cheapness is only fancied and comes about from the low percentage of copper that they carry.

Control "bugs" by rotation, late planting and by arsenical sprays.

Fig. 45. Unsprayed strip in a Kalamazoo field. Summer of 1915. (*Photo by C. W. Waid.*)

If the month of July is cold and wet, late blight is almost sure to do damage on the late crop. Spray applications should be increased when such dangerous weather conditions prevail.

Read carefully the discussion of the type of sprayer and the methods of applying spray mixtures.

THE SPRAYER AND HOW TO APPLY THE SPRAY

The kind of sprayer to be used depends on the acreage. Large acreages require a power sprayer with a spray boom to deliver the spray from the under side of the plants.

Any sprayer is better than none, but a sprayer that gives a high pressure and a fine mist which can penetrate well under the leaves is most efficient. Crops have been saved with a knapsack sprayer in times when late blight was imminent, or even by timely applications of home-made bordeaux mixture put on with crude brooms made of hay or brush.

Careful, thorough spraying as a regular part of the potato-growing program pays. (Fig 45.) An adjustment of the nozzles to deliver the spray upward is preferable to the common practice of using one nozzle above the center of a row. New discs should replace old, corroded ones in order to economize spray mixture.

A farmer can make a home-made arrangement for the nozzles as is shown in the cut. (Fig. 47.) All spray machine manufacturers now supply booms with nozzles adjustable as here recommended.

Experiments have shown that thoroughness in applications brings the results.

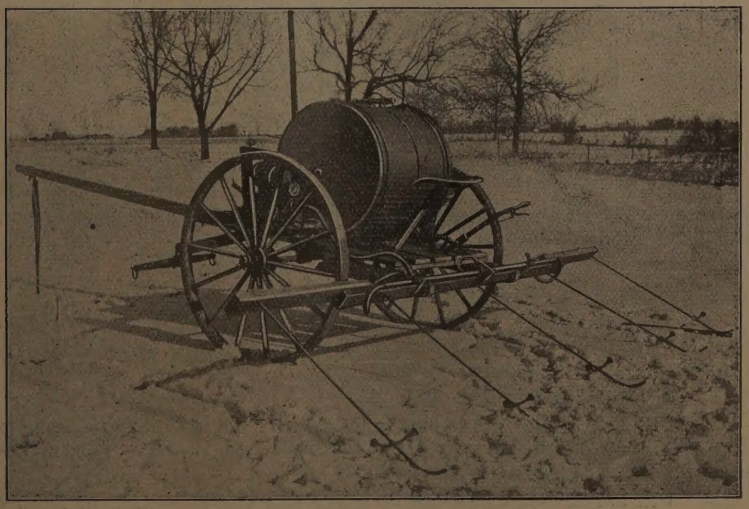


Fig. 47. A simple home-made attachment for arranging nozzles to deliver spray upward. (*Photograph through courtesy of James Redpath.*)

THE MAKING OF BORDEAUX

For Small Acreages

(1) Saw a 50-gallon barrel (vinegar or oil) and make two 25-gallon tubs.

(2) Put 2 pounds of bluestone (called blue vitrol or copper sulphate) in a cloth sack and hang over night in one-half tub of water (12½ gallons). Bluestone dissolves slowly. Hang it the night before so that the sack is just under the surface of the water.

(3) Make a lime paste by slaking 2 pound of fresh lime in one-half pail of water. Stir this into the half tub (12½ gallons) of cold water. Hydrated lime (comes in sacks) may be used. Use 2½ to 3 pounds of

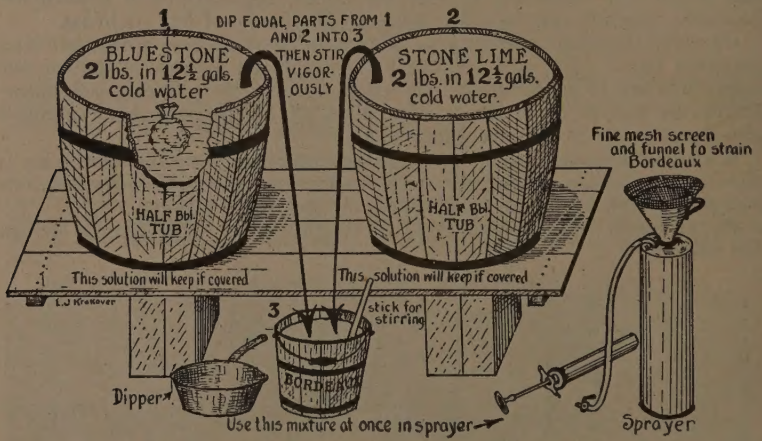


Fig. 48. Making bordeaux mixture for small acreages.

hydrated. Then follow the directions in the picture. This method will make 25 gallons of spray.

For Large Acreages

To make 100 gallon batches:

Bordeaux 4-4-50 or 8-8-100 formula.

(1) Secure four 50-gallon barrels.

(2) Fill barrel No. 1 half-full, and hang 25 pounds of bluestone so that the bluestone is just under the surface of the water. This makes stock bluestone, 1 pound to the gallon.

(3) Fill barrel No. 4 half-full of water and stir 25 pounds of freshly slacked stone lime or about 30 pounds hydrated lime in it. This is the stock lime paste, about 1 pound to the gallon.

The stock solutions will make 300 gallons of spray. They will keep if covered.

(4) Take 8 gallons stock bluestone from barrel No. 1 and add 42 gallons of water in barrel No. 2. (That is, fill the barrel.)

(5) Take 8 gallons of stock lime from barrel No. 4 and add to 42 gallons of water in barrel No. 3.

(6) Run these materials together through a strainer into the sprayer tank. The combination is bordeaux mixture and must be applied at once.

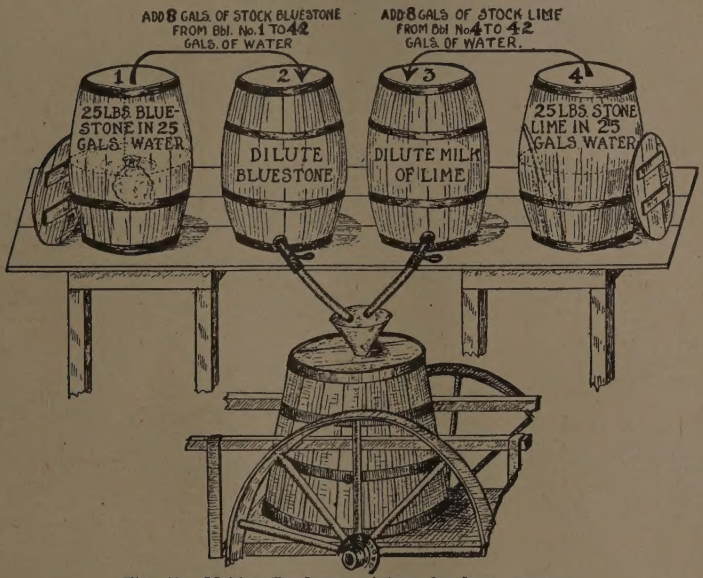


Fig. 49. Making Bordeaux mixture for large acreages.

If the spray tank holds only 50 gallons make the dilution on one-half the above scale. The first batch may be tested with litmus paper to make sure that there is lime enough. If blue litmus paper turns red, add more lime. *With good fresh lime using the amounts given, no test is needed.*